

Ross C. Willoughby Ph.D.

Title: President & Principle Scientist

Institution, Location and Degree

1973-1977 University of Pittsburgh , PA BS (honors) Chemistry
1978-1983 Georgia Institute of Tech., GA Analytical Chemistry

Positions and Honors

Positions and Employment

1983-1985 Chemist Pharmaceutical Development, ICI Americas, Wilmington, DE
1985-1987 Senior Chemist, Applications & Development, Extrel, Pittsburgh, PA
1987-1990 Manager Applications & Development, Extrel, Pittsburgh, PA
1990-1991 Director Applications & Development, Extrel, Pittsburgh, PA
1991-1995 VP, Research & Development, Extrel/Waters, Pittsburgh, PA
1995 Contractor/Consultant, ABB Extrel/Waters
1995- President & Co-Founder, Chem-Space Associates, Inc.

Other Experience and Professional Memberships

1988 American Chemical Society (ACS), American Society for Mass Spectrometry (ASMS)
1992-1995 President & Co-Founder MMPA (a non-profit environmental association)
1989-1993 Chair, American Society of mass Spectrometry (ASMS) LC/MS Interest Group

Honors

1981-1983 Treasurer/Senator-Graduate Senate, Georgia Institute of Technology
1987 Key Employee, Extrel Corporation
1992-1996 President & Co-Founder MMPA (a non-profit environmental association)
1985-2000 Invited Speaker, ACS, ASMS, Montreux LC/MS Symposium, AAAR, SSP, FACSS
1995 Plenary Lecturer, American Association of Aerosol Research (AAAR), International Meeting

Commercial Product Development

1985-1988 ELQ-400™ Quadrupole Mass Spectrometer, Extrel Corp. (triple quadrupole mass spectrom.)
1987 ThermaBeam™ LC/MS Interface, Extrel Corp. (universal mass spectrometry inlet)
1988-1991 Benchmark™, Quadrupole LC/MS, Extrel Corp. (first commercial benchtop LC/MS)
1992-1994 Questor 4™ Process Mass Analyzer, Extrel Corp. (process mass spectrometer)
1993-1994 Merlin™ Component System, Extrel Corp. (research component mass spectrometer)
1992-1995 Integrity™ Mass Detector, Waters Corp. (first commercial LC/MS detector product)

Patents

Monodisperse (MAGIC) and ThermaBeam LC/MS Interfaces

1985-1988 Monodisperse Aerosol Generator, US Patents 4,629,478, 4,687,929, & 4,762,995
1988-1993 Method and Apparatus for Introduction of Liquid Streams into Mass Spectrometer and Other Gas-phase or Particle Detectors, France Patent P3805682.8; US Patents 4,968,885, 4,977,785, & 5,285,064; Japan Patent 49,926,188, UK Patent 8,801,873

Electrospray LC/MS Interface

1998 Method and Apparatus for Improved Electrospray, US Patent 5,838,002
2000 Method and Apparatus for Increased Electrospray Ion Production, US Patent 6,147,345
2001 Electrospray for Chemical Analysis, US Patent 6,278,111

Atmospheric Pressure Ionization

2009 Remote Reagent Ion Generator, US Patent 7,569,812
2006 Laser Desorption Ion Source, US Patent 7,375,319
2007 Remote Reagent Chemical Ionization Source, US Patent 7,253,406
2006 Remote Reagent Chemical Ionization Source, US Patent 7,095,019
2006 Laser Desorption Ion Source, US Patent 7,087,898
2005 Remote Reagent Chemical Ionization Source, US Patent 6,888,132

Atmospheric Focusing of Gas-Phase Ions

2006 Laminated Lens for Focusing Ions from Atmospheric Pressure, US Patent 7,081,621
2006 Ion Enrichment Aperture Arrays, US Patent 7,060,976
2005 Laminated Lens for Introducing Gas-Phase Ions into the Vacuum Systems of Mass Spectrometers, US Patent 6,949,740
2005 Laminated Tube for the Transport of Charged Particles Contained in a Gaseous Medium, US Patent 6,943,347
2005 Ion Enrichment Aperture Arrays, US Patent 6,914,243
2004 Apparatus and Method for Focusing Ions and Charged Particles at Atmospheric Pressure, US Patent 6,744,041
2004 Laminated Lens for Focusing Ions from Atmospheric Pressure, US Patent 6,818,889

Atmospheric Mass Analysis of Gas-Phase Ions

2004 Apparatus and Method for Focusing and Selecting Ions and Charged Particles At or Near Atmospheric Pressure, US Patent 6,784,424

Fragmentation/Collision and Reaction Cell

2004 Efficient Direct Current Collision and Reaction Cell, US Patent 6,781,117

Patents (cont.)

Thin Film Production

2005 Ion and Charged Particle Source for Production of Thin Films, US Patent 6,878,930

Selected peer-reviews publications (in chronological order)

Willoughby, R.C., Browner, R.F., "Combining liquid chromatography with mass spectrometry", IN: Trace Analysis 2, page 69-109, (ed). J.T. Lawrence, Academic Press: New York, 1982.

Willoughby, R.C., "Studies with an aerosol generation interface for liquid chromatography mass spectrometry", Ph.D. Thesis, Georgia Institute of Technology, 1983.

Willoughby, R.C., Browner, R.F., "Monodisperse aerosol generation interface for combining liquid chromatography with mass spectrometry", Anal. Chem. 56, pages 2626-2631 (1984).

Buchner, J.D., Willoughby, R.C., Ketkar, S., "Integrated Thermospray and ThermaBeam sample introduction for LC/MS and SFC/MS", presented at the Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, New Orleans, Louisiana, February 22-26, 1988.

Willoughby, R.C., "Theoretical considerations of aerosol interfaces", presented at the Seventeenth Annual Meeting of the Federation of Analytical Chemistry and Spectroscopy Societies, Cleveland, OH, October 7-12, 1990.

Jones, G.G., Pauls, R.E., Willoughby, R.C., "Analysis of styrene oligomers by particle beam liquid chromatography/ mass spectrometry", Anal. Chem. 63, pages 460-43 (1991).

Sheehan, E.W., Ketkar, S., Willoughby, R.C., "Volatility enhancement of nonvolatile solutes by the combination of a heated target and a solvent-depleted particle beam", Proceedings of the 39th ASMS Conference on Mass Spectrometry and Allied Topics, Nashville, Tennessee, May 19-24, 1991.

Willoughby, R.C., Sheehan, E.W., "The physics of electrospray processes", Proceedings of the 9th Montreux Symposium on Liquid Chromatography Mass Spectrometry, Montreux, Switzerland, November 4-6, 1992.

Sheehan, E.W., Willoughby, R.C., "Photographic studies of electrospray", Proceedings of the 41st ASMS Conference on Mass Spectrometry and Allied Topics, San Francisco, California, May 30-June 4, 1993.

Willoughby, R.C., Sheehan, E.W., Jarrell, A., Pedder, R., Marecic, T.C., "Studies of the physical processes of electrospray", Proceedings of the 41st ASMS Conference on Mass Spectrometry and Allied Topics, San Francisco, California, May 30-June 4, 1993.

Willoughby, R.C., Sheehan, E.W., "The physics of LC/MS: A Thermodynamic Perspective" Proceedings of the 42nd ASMS Conference on Mass Spectrometry and Allied Topics, Chicago, Illinois, May 29-June 3, 1994.

Willoughby, R.C., Sheehan, E.W., "Studies of the physical processes in electrospray", presented at the 4th International Aerosol Conference, Los Angeles, California, August 29-September 2, 1994.

Willoughby, R.C., Sheehan, E.W., "Physical processes of electrospray", presented at the 7th Sanibel Conference on Mass Spectrometry, Sanibel, Florida, January 21-24, 1995.

Willoughby, R.C., Sheehan, E.W., "Studies of ion production mechanisms with electrospray", presented at the Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, New Orleans, Louisiana, March 6-9, 1995.

Sheehan, E.W., Willoughby, R.C., "Stability of liquid jet from an electrospray cone-jet", Proceedings of the 43rd ASMS Conference on Mass Spectrometry and Allied Topics, Atlanta, Georgia, May 21-May 26, 1995.

Willoughby, R.C., Sheehan, E.W., "Secondary droplet and ion formation in electrospray: The Teardrop model", Proceedings of the 43rd ASMS Conference on Mass Spectrometry and Allied Topics, Atlanta, Georgia, May 21-May 26, 1995.

Sheehan, E.W., Willoughby, R.C., "Novel Electrospray Source Design," Presented at the Pittsburgh Conference and Exposition on Analytical Chemistry and Applied Spectroscopy, Chicago, IL, March 3-8, 1996.

Willoughby, R.C., Sheehan, E.W., and Mitrovich, S., "A Global View of LC/MS: How to solve your most challenging analytical problems," Global View Publishing: Pittsburgh (2nd edition, 2002).

Willoughby, R.C., and Sheehan, E.W., "A Global View of MS/MS: How to solve problems with the ultimate analytical tool," Global View Publishing: Pittsburgh (1st edition, 2003).

Willoughby, R.C., "How Do We Eliminate Ion Losses at AP?" available at The LCMS Homepage, www.lcms.com.

Research Support

Ongoing Research

Grant#: **N00014-98-1-0848** (Office of Naval Research)
Title: **Improved Electrospray Ionization Source Development**

Dates: October 1, 2002 thru Present
Principal Investigator: D.P. Fries
Contractor: Chem-Space Associates

Our objective for this contract was the modeling and evaluation of a variety of source configurations for use with the remote submarine sensors, to minimize the gas load on the vacuum system.

Completed Research Support

SBIR Phase I Grant#: **1-R43- GM54492-01**
Title: **Low Cost Mass Detector for Liquid Chromatography**

Dates: 9/15/1996 thru 8/31/1997
Principal Investigator: E.W. Sheehan
Co-Investigator: R.C. Willoughby

The goal of this project was to evaluate the feasibility of forming gas-phase ions produced by electrospraying directing inside the vacuum chamber of a mass spectrometer, thereby eliminating the need for an atmospheric pressure interface and producing a low cost LC/MS mass detector.

SBIR Phase I Grant#: **1-R43-RR14396-01**
Title: **Atmospheric Pressure Focusing Device**

Dates: 9/1/1999 thru 2/28/2001
Principal Investigator: E.W. Sheehan
Co-Investigator: R.C. Willoughby

The goal of this project was to evaluate the feasibility of improving the collection efficiency of atmospheric, or near atmospheric ionization sources (such as, electrospray, atmospheric pressure ionization, discharge ionization, thermospray) by means of both direct or alternating current (RF quadrupoles) focusing

SBIR Phase I Grant#: **1-R43-RR14383-01**
Title: **Counter Ion Improved Electrospray Using Counter-Ion Impingement**

Dates: 3/1/2000 thru 4/1/2003
Principal Investigator: R.C. Willoughby
Co-Investigator: E.W. Sheehan

The goal of this project was to evaluate the feasibility of improving the ion current generated by the electrospray process by injecting counter-ions, from an external discharge, into the electrospray liquid-cone.

SBIR Phase I Grant#: **1-R43-RR15984-01**
Title: **Atmospheric Pressure Quadrupole Mass Spectrometry**

Dates: 3/1/2001 thru 3/31/2003
Principal Investigator: R.C. Willoughby
Co-Investigator: E.W. Sheehan

The goal of this project was to evaluate the feasibility of using an atmospheric RF/DC quadrupole mass filter utilizing a concentric flow of gas down the axis of the quadrupole to separate ions based on their mass-to-charge ratio.
